Levels of Trace Metals in Atmospheric Suspended Particulate Matters in Dhaka, Bangladesh

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Abstract

The concentration of five trace metals namely arsenic, cadmium, copper, lead and zinc were determined in suspended particulates matters (SPM) at Motijheel area in Bangladesh between March and April. The SPM samples were collected on Teflon filters by a low volume sampler. The average concentrations of measured trace metals were 9.83 ngm^{-3} for As, 4.46 ngm^{-3} for Cd, 58.0 ngm^{-3} for Cu, 186.3 ngm^{-3} for Pb, and 1049.7 ngm^{-3} for Zn. The level of arsenic exceeded the German "target" value but remained below the "orientation" value. Cadmium concentrations in Dhaka approached to WHO (World Health Organization) guideline value (50 ngm^{-3}). The level of lead was also lower than the WHO guideline value (500 ngm^{-3}) for Bangladesh, probably due to the ban of leaded gasoline in Bangladesh. High zinc concentration was observed, which might be due to rapid urbanization and industrial growth in Dhaka. The elevated levels of some of these five trace metals were observed in Dhaka, which were much lower than the reported values of South Asian cities (e.g., Lahore, Kolkata) and much higher than European and United States sites.

Keywords: Trace Metals, Suspended Particulates Matter, Air Quality, Health Effect

Introduction

Trace metals in atmospheric particulate matters cause serious health hazard since they can be absorbed into human lung tissues during breathing. Anthropogenic emissions increase the levels of trace metals in suspended particulate matters well above the natural background levels (Pitts Jr. and Finlayson-Pitts, 2000). Air pollution is a serious public health problem in the developing countries especially in Dhaka, Bangladesh due to the rapid growth of the cities (Faiz and Strum, 2000). Dhaka, with about 15 million people and 7% increase of population per year (Karim, 1999), is exposed to the high levels of trace metal pollutions from a variety of sources (Faiz and Strum, 2000).

Due to the presence of high-level toxic elements, Dhaka has been considered as one of the most polluted cities in the world (Karim, 1999). Trace metals pollution in the atmosphere is mainly related to the inorganic fraction, which is released from various kinds of vehicles, brickfields, constructions, tanneries, navigation, corrosion of metallic parts, soil dusts, etc., (Azad and Kitada, 1998; Dannecker *et al.,* 1990; Fang *et al.,* 2003). Bangladesh Atomic Energy Commission (BAEC) (Khaliquzzaman *et al.,* 1997) reported 463 ngm^{-3} lead in Dhaka air during the dry months in 1997. For mega cities in India and Pakistan high exceedances of the WHO guideline values for cadmium and lead were reported (Sharma and Patil, 1992; Smith *et al.,* 1996). Arsenic is the element with the widest focus of public attention, mainly due to the endemic health problems of hundreds of thousands of people in Bangladesh and West Bengal, India, caused by arsenic - contaminated groundwater (Smith *et al.,* 1996). Its exposure to ground water is well understood, but not much information is available about the atmospheric level of this contaminant in Bangladesh. Also for copper and zinc no systematic measurements of particulate air pollution in Bangladesh have been performed until now. So the objective of this study was to investigate the atmospheric levels of arsenic, cadmium, copper, lead, and zinc in suspended particulates matters between March and April 2003 at Motijheel, Dhaka, Bangladesh.

Materials and Methods

Sampling: Samples were collected by a low volume sampler as daily average with about 20 m^3 air volume. The samplers were equipped with filter holders using supported PTFE filters (Pall Corp., Gelman Lab., Zefluor, 1.0µm, 47mm diameter). Sampling periods were approximately 12h

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- during daytime at temperatures in the range from 24ºC to 34ºC. Field blanks were determined for each sampling site and considered for the calculation procedures. The loaded filters were stored in clean Millipore Petri dishes and kept in a refrigerator during the sampling period to minimize losses due to volatilization and evaporation.

Sites Description (Motijheel, Dhaka): The sampling was carried out from March 29 to April 04, 2003 at Motijheel in a highly populated commercial and traffic part in Dhaka. The country lies in the eastern part of south Asia, surrounded by India on the west, the north and northeast, Burma on the southeast, and the Bay of Bengal on the south. There is no hilly region around Dhaka; it is surrounded by rivers from all sides. Dhaka is the center of commerce and industry of Bangladesh.

Methods: As, Cd, Cu, and Pb were determined by Atomic Absorption Spectroscopy (AAS), (Perkin Elmer, Model 370 equipped with a graphite furnace HGA 74). Zn was determined by AAS with a Perkin Elmer, Model 403 with an acetylene air flame. The detection limit of these metals and the analytical wavelength of each metal are given in Table 1. The whole filters were extracted with 5 ml of 10% HNO_3 (v/v) for about 40 minutes in an ultrasonic bath. The extracts were taken for the analysis of the metals. Calibration of individual metal was done with five standard solutions of different concentrations. The concentrations of the trace elements on the filters were expressed in ngm^{-3} at sampling conditions.

Table 1. Analytical wavelengths and detection limits (in solutions and for sampling conditions) of the trace metal levels by atomic absorption spectroscopy.

	Wave length (λ nm)	Detection limit ($ngmL^{-1}$)	Detection limit (ngm^{-3})
As	193.7	2.0	0.5
Cd	228.8	0.2	0.05
Cu	324.5	1.0	0.25
Pb	283.3	0.5	0.125
Zn	213.8	0.5	0.125

Results and Discussion

Trace Metals Concentrations at Motijheel, Dhaka: The levels of five trace metals (As, Cd, Cu, Pb, and Zn) were determined from Motijheel, Dhaka, Bangladesh during March, 29 to April 4 in suspended particulate matters (SPM). The overall concentrations of the trace metals were lower than previous measurements in Dhaka and comparable or lower than other Southeast Asian cities, but much higher than European and Unites States sites (TA-Luft, 1995; WHO, 1997). The concentrations of the individual trace metals are given in Table 2.

Table 2. Trace metals levels (ngm^{-3}) in suspended particulate matters (SPM) at Motijheel, Dhaka, Bangladesh during March and April, 2003.

	As	Cd	Cu	Pb	Zn
29-Mar-03	10.5	5.61	42.5	76.0	298
30-Mar-03	13.8	8.39	72.0	144	612
31-Mar-03	8.23	5.21	37.7	168	939
01-Apr-03	6.94	2.29	61.6	121	790
02-Apr-03	10.3	2.96	81.8	208	1200
03-Apr-03	11.2	2.84	55.6	244	1526
04-Apr-03	7.82	3.91	52.1	343	1983
Average	**9.83**	**4.46**	**58.0**	**186.3**	**1049.7**
WHO	-	5.00	-	500	-
TA-Luft	a. 13, b. 5	-	-	-	-

a. orientation value, and b. target value of the German TA-Luft

Arsenic (As): The daily average concentration of arsenic ranged from 6.94 to 13.8 ngm^{-3} with an average value of 9.83 ngm^{-3}, which is about eighteen times lower than the previous measurements of Biswas *et al.,* 2003. The elevated concentration of arsenic in Dhaka air presumably due to the geogenic source. The arsenic concentration in ground water is very high (WHO guideline value) in many parts of the country. Here we compare the measured arsenic concentration with Germen threshold values edited in the "TA-Luft, 1995", based on two different "risk" levels. From these two "risk levels" an "orientation" and a "target" value were derived (TA-Luft, 1995). The average concentration of arsenic (9.83 ngm^{-3}) was much lower than the "orientation value" of the German "TA-Luft" of 13 ngm^{-3}, but it was about two times higher than the "target value" of the German "TA-Luft" (5 ngm^{-3}). Still, the average arsenic concentration in Dhaka is much lower than in other south Asian mega cities, namely Lahore, Bombay and comparable with USA and European sites (Table 3: Chatterjee, 1988; Goforth and Christoforou, 2006; Hien, *et al.,* 1999; Mayer, 1981; Pike and Moran, 2001; Sharma and Patil, 1992; Smith *et al.,* 1996; Puxbaum, 2011).

Table 3. Comparison of the trace metals levels at Motijheel, Dhaka, Bangladesh and other international studies (Units are in ngm^{-3})

Name	As	Cd	Cu	Pb	Zn	References
Bangladesh						
Dhaka	9.83	4.46	58.0	186.3	1049.7	Current Study
Dhaka	177.8	-	142.2	1238	451	Biswas et al., 2003
Austria						
Vienna (Oct. 1979)	n.d.	3.03	105	1360	307	Mayer, 1981
Vienna (1999/2000)	1.07	0.47	12.5	25.2	39.7	Puxbaum, 2001
India						
Calcutta	260	n.d.	1120	6630	3040	Chatterjee et al. ,1988
Bombay	270	40	290	550	210	Sharma and Patil, 1992
Pakistan						
Lahore	29.5	43.5	420	3920	27700	Smith et al., 1996
USA						
New Castle	0.7	0.2	2.0	5.0	13.0	Pike et al., 2001
Lake Hartwell	n.d.	0.77	14.6	15.04	<2.99	Goforth et al., 2006
Vietnam						
Ho Chi Minh City	1.47	n.d.	1.39	163	203	Hien et al.,1999

n.d. = not determined

Cadmium (Cd): The daily average concentration of cadmium varied from 2.29 to 8.39 ngm^{-3} with an average value of 4.46 ngm^{-3} (Table 2). The total average cadmium concentration at Motijheel, Dhaka was very close to the WHO guideline value of 5.0 ngm^{-3} (Table 2). The daily average concentration of cadmium exceeded the WHO guideline value in three events out of eight samples. The higher cadmium concentration in Dhaka may be due to the release of cadmium from different industrial mechanical processes inside the city. However, the cadmium has the lowest concentration among the measured trace metals in this study. Therefore care should be taken about the sources and the remedy of the high level of cadmium pollution in Dhaka, Bangladesh as it has serious impact on human health.

Copper (Cu): The daily average concentration of copper was highest on April 2, 2003 (81.8 ngm^{-3}) and the lowest on March 31, 2003 (37.7 ngm^{-3}) among the measured period. The total average copper concentration (58.0 ngm^{-3}) was about 2.4 times lower than the previous measurements by

Biswas *et al.,* 2003. The average copper concentration in Dhaka is slightly lower than the value (65 ngm^{-3}) obtained in Bangkok Metropolitan Region, Thailand (Chuersuwan, *et al.,* 2008).

Lead (Pb): The daily average lead concentration ranged from 76 to 343 ngm^{-3} with an average value of 186.3 ngm^{-3}, which is less than half of the Air Quality Standard for Bangladesh (DoE) as well as the WHO guideline value (Figure 1). A 17-month survey conducted by the scientists of BAEC detected 463 ngm^{-3} lead at $PM_{2.5}$ in Dhaka air during the dry months (between November 1994 and January 1996) (Khaliquzzaman *et al.,* 1997). Salam *et al.,* 2003 also reported the higher value (279 ngm^{-3}) of lead in Dhaka city; on the other hand the lead concentration in rural areas in Bangladesh is still bellow the detection limit. The relatively high lead concentration in Dhaka could predominantly originate from burning of fossil fuel from large number of vehicles. Emissions from road or windblown dust, brickfields or other industries may also have significant contribution to the lead pollution in Dhaka City. Figure 1 shows that the current study has the lowest value for lead in Dhaka city as compared to the previous measurements. The lower value of lead could probable be due to use of lead free gasoline in Bangladesh.

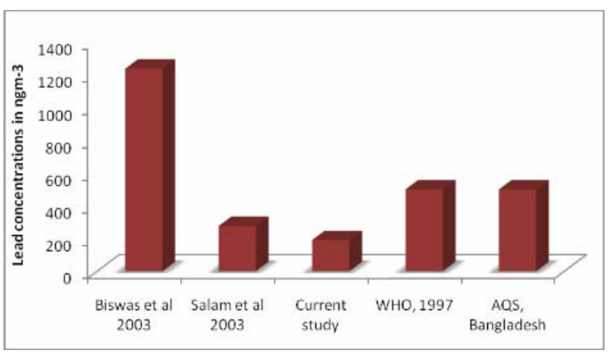

Figure 1. Comparison of the lead (Pb) levels at different measurements in Dhaka, Bangladesh with Guideline values. WHO = World Health Organization, AQS = Air Quality Standard.

Zinc (Zn): Zinc exhibited the highest concentration among the measured trace metals in Motijheel, Dhaka. The average concentration was 1049.7 ngm^{-3} with a variation between 298 and 1983 ngm^{-3} (Table 2). Biswas et al., 2003 also observed about 2.3 times lower zinc concentration in Dhaka as compared to the current study. However, high level of zinc concentration in Dhaka city may be due to the rapid urbanization and industrial growth in and around Dhaka city.

Comparison with other studies: The data listed in Table 3 include a small overview of the trace metals analyzed at other sites. This demonstrates that the levels of trace metals at Motijheel, Dhaka were typically much lower than observed in other Asian cities like Lahore, Pakistan; except for zinc, in Bombay, India but higher than at other Asian sites like Ho Chi Minh City, Vietnam (Table 3). However, trace element levels in Dhaka are much higher than any European cities like Vienna, Austria (Table 3), Antwerp and Ghent, Belgium (Van Borm, 1989).

In the case of lead, the ban of lead additives for petrol in North America, Europe and many other countries led to a dramatic decrease of emissions, which is reflected now a days by low levels observed even in large cities of Europe and USA (Table 3). Cadmium, copper and zinc are emitted in North America and Europe from many sources, but also for those components a considerable reduction was achieved in the past decades by the prescription of waste incineration, the use of clean fuels and the ban of toxic trace metals as part of colors and consumer products (e.g. compare trace element levels in Vienna 1979 vs. 1999/2000 - Table 3) (Mayer, 1981; Puxbaum, 2001). These changes may at large explain the differences of cadmium, copper, lead and zinc concentrations between the urban Dhaka and the urban European and US sites. For Arsenic the situation is more complex. Geogenic sources may be responsible for regional elevated levels of As also in the atmospheric aerosol. Elevated levels were not only found in Dhaka, but also at several urban sites in Europe (e.g. Debrecen, Antwerp, Ghent- Van Borm, 1989). However, in Pakistan and Indian urban sites arsenic levels were even higher by factors of 3-27 as compared to the average level observed in Dhaka. Since groundwater sources deliver arsenic levels, which are considered harmful to the public health, (Das, 1995) in this case the intake by inhalation from atmospheric sources has to be considered also.

Conclusion

High concentrations of trace metals in atmospheric particulate matters are a great threat for the public health in Dhaka, Bangladesh. Therefore, it is very important to determine the concentration levels of trace metals as per WHO guidelines. Arsenic, cadmium, copper, lead, and zinc in suspended particulate matters (SPM) were measured in Motijheel, Dhaka between March 29 and April 4, 2003. At Motijheel, Dhaka, the arsenic levels at the urban sites were below the "orientation" value of the German TA-Luft but exceeded the "target" value by a factor of about two. The average cadmium concentration was below but close to the WHO guideline value. The lead concentration was below the WHO guideline value and Air Quality Standard for Bangladesh, and also showing decreasing tendency as compared to the previous measurements in Dhaka. The zinc concentration showed higher value when compared to previous studies. Compaired with other Asian cities, the determined concentration of trace metals at urban Dhaka exhibited typically lower levels than observed in Lahore, Bombay but higher than other Asian sites like Ho Chi Minh City and much higher than recent values in USA and European sites.

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References

Azad, A.K. and Kitada, T. 1998. Characteristics of the air pollution in the city of Dhaka, Bangladesh in winter. *Atmos. Environ.* **32**, 1991-2005.

Biswas, S.K., Tarafdar, S.A., Islam, A., Khaliquzzaman, A., Tervahattu, H. and Kupiainen, K. 2003. Impact of unleaded gasoline introduction on the concentration of lead in the air of Dhaka, Bangladesh*. J. Air & Waste Manag. Assoc.* **53**, 1355-1362.

Chatterjee, D., van Vaeck, L. and van Espen, P. 1988. Calcutta pollutants: Part 2. Polynuclear aromatic hydrocarbons and some metal concentrations on air particulates during winter 1984. *Intern. J. Environ. Ana. Chem.* **32**, 109-120.

Chatterjee, A., Das, D., Mandal, B.K., Chowdhury, T.R., Samanta, G. and Chakraborti, D. 1995. Arsenic in ground water in six districts of west Bengal, India: the biggest arsenic calamity in the world. Part 1: arsenic species in drinking water and urine of affected people. *Analyst,* **120**, 643-650.

Chuersuwan, N., Nimrat, S., Lekphet, S. and Kerdkumrai, T. 2008. Levels and major sources of $PM_{2.5}$ and PM_{10} in Bangkok metropolitan region. *Environ. Int.* **34**, 671-677.

Dannecker, W.B., Schroder, B.H. and Stechmann, S.T. 1990. Organic and inorganic substances in highway tunnel exhaust air. *Sci. Total Environ.* **93**, 125-133.

Das, A.K., Chakraborty, R., Cervera, M.L. and Guardia, M. de la. 1995. Metal speciation in solid matrices. *Talanta,* **42**, 1007-1030.

Faiz, A. and Strum, P.J. 2000. New directions: air pollution and road traffic in developing countries. *Atmos. Environ.* **34**, 4745-4746.

Fang, G.C., Chang, C.N., Chu, C.C., Wu, Y.S., Fu, P.P.C., Yang, I.L. and Chen, M.H. 2003. Characterization of particulate, metallic elements of TSP, $PM_{2.5}$ and $PM_{2.5–10}$ aerosols at a farm sampling site in Taiwan, Taichung. *Sci. Total Environ.* **308**, 157-166.

Goforth, M.R. and Christoforou, C.S. 2006. Particle size distribution and atmospheric metals measurements in a rural area in the South Eastern USA. *Sci. Total Environ.* **356**, 217-227.

Hien, P.D., Binh, N.T., Truong, Y. and Ngo, N.T. 1999. Temporal variations of source impacts at the receptor, as derived from air particulate monitoring data in Ho Chi Minh City, Vietnam. *Atmos. Environ.* **33**, 3133-3142.

Karim, M.M. 1999. Traffic pollution inventories and modeling in metropolitan Dhaka, Bangladesh. *Trans. Res.* Part D **4**, 291-312.

Khaliquzzaman, M., Biswas, S.K., Tarafdar, S.A., Islam, A., Khan, A.H. 1997. Trace element composition of size fractionated airborne particulate matter at urban and rural areas in Bangladesh. Report AECD/AFD-CH/6-4.

Mayer, M. 1981. Beiträge zur Untersuchung der Korngrößenverteilung von Schwermetallen in atembaren Stäuben, *Diplomarbeit*, Technical University of Vienna, Austria. p. 110.

Pike, S.M. and Moran, S.B. 2001. Trace elements in aerosol and precipitation at New Castle, NH, USA. *Atmos. Environ.* **35**, 3361-3366.

Pitts Jr, J.N. and Finlayson-Pitts, B.J. 2000. *Chemistry of the upper and lower atmosphere: theory, experiments and applications*, Academic Press, Florida, New York.

Puxbaum, H. 2011. Austrian Project for the Health Effect of Particulate Matters (AUPHEP).

Salam, A., Bauer, H., Kassin, K., Ullah, S.M. and Puxbaum, H. 2003. Aerosol chemical characteristics of a mega-city in Southeast Asia (Dhaka, Bangladesh). *Atmos. Environ.* **37**, 2517-2528.

Sharma, V.K. & Patil, R.S. 1992. Chemical composition and source identification of Bombay aerosol. *Environ. Technol.* **13**, 1043- 1052.

Smith, D.J.T., Harrision, R.M., Luhana, L., Casimiro, A.P., Castro, L.M., Tariq, M.N., Hayat, S. and Quraishi, T. 1996. Concentrations of particulates airborne polycyclic aromatic hydrocarbons and metals collected in Lahore, Pakistan. *Atmos. Environ.* **30**, 4031-4040.

TA-Luft. 1995. 4. Verwaltungsvorschrift zum Bunde simmissions schutzgesetz der BRD, Mai 1995.

Van Borm, W.A. 1989. Characterization of individual particles in the Antwerp aerosol. *Atmos. Environ.* **23**, 1139-1151.

World Health Organization (WHO). 1997. Air Quality Guidelines for Europe. Copenhagen: WHO regional office for Europe, WHO Regional Publications, European Series.